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X-ray Emission from a Gas Puff Target Irradiated with a Nanosecond Laser Pulse

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A hot and dense plasma can be produced by irradiation of a gas puff target with a nanosecond high-power laser pulse. The plasma emits strong x-ray radiation in 1-keV energy range. It was shown that x-ray output for the gas puff target can be greater than the x-ray output for laser-irradiated solid targets. The gas puff target is considered to be used as a debrisless laser-produced x-ray source for lithography applications. It was also shown that the laser-irradiated gas puff plasma is an ideal source for the high-resolution spectroscopic studies of complex spectra of the multicharged ions. Recently, the elongated gas puff target irradiated with a high-power laser beam focused to a line has been successfully used in soft x-ray laser experiments.

In the paper we present the investigations of the x-ray emission form plasmas produced using high-pressure gas puff targets with Nd:glass laser pulses of about 5-10 J of energy and duration of 1 ns. The experiments were carried out at the Institute of Optoelectronics, Warsaw. The gas puff targets were created by pulsed injection of a small amount of gas from a high-pressure electromagnetic valve into vacuum. The gas backing pressure in the valve was 15 at. The gas puff targets were characterised with x-ray backlighting technique, using a laser-produced plasma as an x-ray point source, and laser interferometry as well. The maximum density of gas for the gas puff xenon target, at the distance of about 0.25 mm from the nozzle output, was 10 mg/cc, that corresponds to the gas pressure of about 2 bar in room temperature. The laser beam was focused onto the gas puff target perpendicularly to the flow of gas. The laser spot of about 0.1 mm in diameter was placed symmetrically at the axis of the nozzle. The distance between the centre of the laser spot and the nozzle output was changed from about 0.2 mm up to 1.0 mm.

To measure x-ray emission from laser-irradiated gas puff targets we have used and x-ray crystal spectrographs and x-ray pinhole camera. Two focusing spectrographs with the spherically bent mica crystals and one with the flat CsAP crystal, equipped with a 0.5 mm wide slit, were applied. X-ray spectra of radiation of multicharged ions in the plasma have been measured with high resolution. From the registered x-ray spectra of helium-like argon ions the maximum electron temperature of the plasma at 620 eV and the electron density at 10^{21} cm^{-3} was estimated. High-resolution spectra of neonlike krypton ions have been also measured.

It was shown that the interaction process strongly depends on the pressure of gas in the laser focus region. For the maximum pressure, we have observed the self-focusing effect, which appears by a characteristic shape of x-ray images obtained with a pinhole camera, and by a small burn pattern on a photographic paper placed behind the gas puff target. In this case, we have also observed the reflection of the laser radiation from the critical density plasma. For lower values of the gas pressure in the interaction region, the self-focusing effect did not occur, and the plasma temperatures and densities were considerably lower. No reflection of the laser radiation from the target was observed.

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